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13. ABSTRACT (Maximum 200 words) Report Developed under SBIR Contract #DAAH01-98-C-R063. This effort assessed the feasibility of building a Dynamic Built-In Test & Simulation (DBITS) System, based on Santa Barbara Infrared's MIRAGE IR resistive micro emitter array, that provides dynamic imagery to the optical systems in the Army's IBAS sight. Our research involved understanding the IBAS BSA configuration and functionality, BSA optical analysis, the BSA's role in factory testing and BIT, analyzing a DBITS test design, surveying potential visible emitter candidates, and analyzing compact packaging of the MIRAGE emitter and the emitter drive electronics. Our efforts resulted in the selection of a visible emitter, a set of recommended DBITS tests, identification of a potential compact vacuum package for the MIRAGE emitter, presentation of a drive electronics packaging concept. Mechanical and electronic aspects are highly feasible. Design of an appropriate optical system is the biggest challenge. In addition, further research is suggested in the area of non-uniformity correction. A suggested DBITS demonstration system has been defined and a path for the resolution of open technical issues is presented. Potential applications include IR missile and imager testing, testing of laboratory IR imaging systems, PVE systems, military FLIRs, portable testing applications and testing of military training systems.				
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1. Introduction

In November, 1997 Santa Barbara Infrared, Inc. (SBIR) began a Phase I Small Business Innovation Research Program on the topic of Dynamic Built-in Test/Simulation (DBITS) for the Army. This is the final report on the DBITS Phase I program.

1.1 Objectives

The principle objectives of the DBITS Phase I study were as follows:

1. Study the feasibility of the DBITS concept for the video and FLIR imaging systems of the Army's IBAS sight. The study should focus on the feasibility of adding DBITS capability to the IBAS Boresight Assembly (BSA) subsystem MIS-50058.
2. Develop and define a configuration for a proof of concept DBITS system.

DBITS is a concept that combines dynamic scene simulation capabilities in the visible and infrared spectrums to expand existing internal Built-In-Test (BIT) capabilities of systems with imaging sensors. The Army's requirement for this study is to evaluate the applicability of such a test system to the existing IBAS sight that has both visible and infrared imaging optical systems.

SBIR has previously presented to the Army the capabilities of the MIRAGE (Multi-Spectral Infrared Animation Generation Equipment) laboratory infrared simulation system. The technological centerpiece of MIRAGE, the MIRAGE emitter, has unique properties that make it ideal for inclusion in compact systems such as DBITS. SBIR's tasks in the DBITS Phase I study included understanding the Army's IBAS, and its BSA subsystem and selecting components that would allow the addition of the MIRAGE emitter and a compatible visible emitter into the IBAS system. A research program was designed to assess the feasibility of these tasks and make preliminary technical design judgments for future DBITS work. The research is described in detail in Section 2. Section 3 is a summary of the results of DBITS Phase I and an assessment of the feasibility of continued DBITS work. SBIR's recommendations for Phase II work on DBITS are included in Section 4.

2. Phase I Research

2.1 Overview

The essence of the DBITS concept is to improve the built-in-test functionality of imaging systems that include trackers or other forms of machine vision. In the past artificial scene generation systems, particularly infrared simulators, were large, cumbersome systems that were not suited for inclusion in compact field test apparatus. The reason for this study is that recent advances in both visible emitters and infrared simulation technology have brought the technology very close to the point where it may routinely be applied to tests systems built into weapons and sights such as the IBAS sight. The purpose of this Phase I study is to assess whether a built in dynamic test system is now feasible in the Army's IBAS sight, and whether appropriate dynamic and static tests can be presented to the sight's optical systems.

This section of the Phase I report presents a brief overview of the study areas. A detailed discussion of each of the study areas is presented in Section 2.2.

2.1.1 MIRAGE Emitter

The first part of the Phase I research overview is a review of the features and capabilities of the MIRAGE infrared emitter. The MIRAGE emitter is part of a larger system developed by SBIR and Indigo Systems that is being offered as a turnkey solution for laboratory infrared scene simulation requirements. The MIRAGE emitter is a 512x512 pixel resistive array that allows dynamic simulated infrared imagery over a wide simulated temperature range and high frame rates. The MIRAGE emitter combines a very large, highly integrated mixed signal integrated

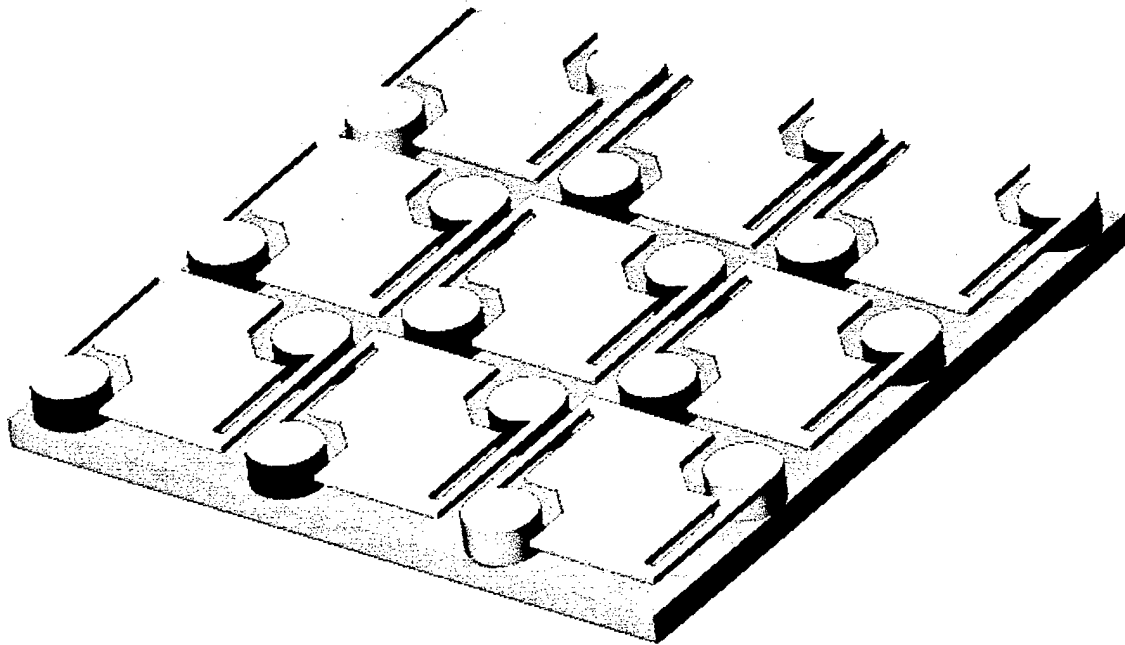


Figure 1. Illustration of a section of the MIRAGE emitter array

circuit and an array of 262,114 individual bridge resistors which form the thermal pixels in the infrared emitting system. The integrated circuit, called a Read-In Integrated Circuit (RIIC), manages the input of digital pixel data into the array, converting the digital data into an analog voltage and presenting the voltage to the appropriate pixel resistor. The resistors in the array are thermally isolated structures with a deposited thin film resistor heater. Each resistor is suspended over a corresponding RIIC unit cell circuit in a manner suggested by Figure 1 where the dark bottom layer represents the silicon RIIC. A thermal image is produced by applying various voltages to individual resistors. Each resistor's voltage is controlled by the RIIC unit cell analog circuits with one unit cell per resistor. In addition to providing the electrical connection to the unit cell the resistor legs are also the thermal conduction path for removing heat from the resistor. Since the emitter operates in a vacuum and the legs are poor thermal conductors, the resistor heats as voltage is applied, coming to equilibrium when the thermal conduction allowed by the

by the legs balances the power applied. The design of the MIRAGE resistor structures allow for high speed, low power imaging, while the proprietary RIIC unit cell exhibits very low noise operation.

The MIRAGE emitter resistors and RIIC are fabricated as separate structures and brought together in a proprietary process developed by Rockwell Science Center/Boeing. The high-performance CMOS IC that is hybridized to the resistor array to form the emitter provides two high-speed, high-accuracy DACs that handle two 16 bit pixel input words simultaneously. These DACs convert digital pixel data to the analog voltages used in heating individual resistive pixels. While the high-speed digital and analog circuitry of the RIIC allow a frame rate up to 200 frames per second, droop-free operation at an IBAS-compatible rate of 30 frames per second is also assured by careful RIIC unit cell design. In addition to providing for very low noise the pixel unit cell circuit architecture allows two modes of operation. One emitter operation mode is double sample and hold or snapshot mode operation. In this mode all emitter pixels update simultaneously at the end of a frame data input cycle. The MIRAGE mode of operation for DBITS is raster mode, which allows each new frame of data to be painted down the emitter face in a manner similar to a television screen. This raster mode will be used, along with a frame rate of 60 frames per second, for infrared imaging for the scanning IBAS FLIR. Synchronization of the FLIR and the emitter will be carefully controlled.

Table 1 lists some of the performance specifications of the standard MIRAGE infrared emitter.

Emitter Array Size	512 x 512
Emitter Pixel Pitch	39 μ m
Emitter Pixel Geometric Fill Factor	46%
Emitter Pixel Time Constant	5ms.
Emitter Resistor Commanded Temperature Range	To 600C above substrate
Substrate Temperature Range	-50C to + 40C
Non Responsive Pixels	< 0.25%, no out rows or out columns
Emitter Data Input	Dual 16-bit Digital Data Ports
Frame rate	10 to 200 frames per second
System 7-10.5 μ m Apparent Temperature Performance , 22C ambient temperature	13°C to 280°C

Table 1. MIRAGE Emitter Performance

The MIRAGE emitter provides the basis around which the IBAS DBITS system will be assembled.

2.1.2 ITAS/IBAS BSA

The IBAS sight has been proposed by the Army for the first application of DBITS. As part of the Phase I research, SBIR contacted Raytheon TI Systems (RTIS) in Dallas, the Army contractor on the IBAS sight, and discussed the basics of the design and operation of the system. SBIR learned that the IBAS sight is used in target acquisition and tracking and for TOW missile guidance.

The IBAS sight has two principal vision systems, each with its own optical port and optical path, but with similar field of view. The direct view system or DVO includes a direct view periscope sight which is supplemented by a video camera. This direct view sight also contains the Xenon Beacon Tracker (XBT) detector. This detector picks up a signal from the TOW missile after it has been fired, and is en route to the selected target. With this signal the XBT system guides the missile to the target via a wire guidance system. A FLIR system accompanies the direct view target optical system, allowing target acquisition and aiming in nighttime or battlefield obscured conditions. A summary of the information learned from RTIS including the basic pixel resolutions, fields of view, and other related parameters of the two electronic imaging systems in the IBAS sight are shown in Table 2.

The operation of the IBAS' BSA boresight collimator was studied. This small subsystem is used to align the XBT, DVO and FLIR systems. The specifications of the BSA optical system were used to calculate the optical projection parameters of the MIRAGE emitter and the visible emitter.

2.1.3 IBAS Testing

The goal of this portion of the Phase I study was to understand the current role of the BSA in both factory tests and BIT. With DBITS added to the IBAS BSA, the BSA should retain full functionality, whether in Built-in-Test (BIT) applications or in factory tests. To understand the use of the BSA in IBAS in factory testing, a study was conducted of the RTIS document "Improved Bradley Acquisition (IBAS) Test Requirement Specification (TRS) for Target Acquisition Subsystem (TAS)". TRS No. ITRS-IBAS-TAS-TPS. This document describes the factory tests of the IBAS system. Discussions with RTIS personnel were also conducted on the current state of Built-in-Test (BIT) in the IBAS.

2.1.4 Test Design

In this portion of the study DBITS test design was considered. Specific tests were designed and the hardware impacts of the tests analyzed. The results are discussed in Section 2.2.3

2.1.5 Survey Visible Emitters

Since the IBAS sight contains a visible target acquisition and tracking system as well as a FLIR imager, the DBITS system must contain a method of providing synthetic dynamic imagery to the IBAS visible band system. A survey of the current state of the art in miniature visible emitters was undertaken and number of different approaches were discovered. A set of selection criteria was developed and then applied to each of the visible emitters to select a candidate for inclusion in the DBITS system. The survey and results are discussed in detail in Section 2.2.4.

2.1.6 Emitter Packaging

An approach to compact packaging of the MIRAGE emitter was the goal of this section of the Phase I study. While all visible emitters have some form of packaging and interconnection built in, the MIRAGE emitter requires a complete package re-design for DBITS use. As with most resistive infrared emitters the MIRAGE emitter operates in a vacuum. The MIRAGE laboratory system emitter package is a relatively large evacuated chamber designed to facilitate the removal of large amounts of thermal energy generated in the imaging process. The vacuum seal of this package is not intended to hold operational levels of vacuum for over one week. A package intended for field use in an IBAS sight must be both compact for mounting on the BSA and hold vacuum for a period of several years. To assist in scoping the challenge of packaging the MIRAGE emitter for compact, permanently sealed use, a leading vendor of commercial infrared detector packages was contacted and a suitable packaging solution was arrived at.

2.1.7 Electronics

Electronic design for a DBITS concept system was considered. The major issues were a partitioning of system functions required by the physical constraints of the IBAS system and the issue of compact storage of dynamic imagery.

2.2 Research Details

2.2.1 IBAS SIGHT AND BSA

The operation of the two electronic sighting systems of the IBAS sight is summarized in the data shown in Table 2.

IBAS DVO Video Sight	
Pixel Raster – type	Interlace
Horizontal Number of Pixels	768
Vertical Number of Pixels	493
Field of View – Wide	7.50 degrees vertical x 10 degrees horizontal
Field of View – Narrow	2.00 degrees Vertical x 2.67 degrees Horizontal
Pixel Field of View – Narrow	70.8urad vertical x 60.6urad horizontal
Pixel Field of View – Wide	265urad vertical x 227urad horizontal
Pixel Physical Size	11 μ m horizontal x 13 μ m vertical
IBAS FLIR	
Pixel Raster	Non-Interlace (Scanned)
Horizontal Number of Pixels	1315
Vertical Number of Pixels	480
Field of View – Wide	7.50 degrees vertical x 13.33 degrees horizontal
Field of View – Narrow	2.00 degrees vertical x 3.56 degrees horizontal
Pixel Instantaneous Field of View Narrow	108.8 μ rad vertical x 80.2 μ rad. vertical
Pixel Instantaneous Field of View Wide	408 μ rad vertical x 301 μ rad. horizontal
Pixel Physical Size	28 μ m horizontal x 38 μ m vertical
Focal Length	13.75 inches (f2.5)

Table 2. IBAS sight Principal Specifications.

The two IBAS optical systems have similar fields of view, although the FLIR has a non-standard aspect ratio. Both visible and FLIR optics have a wide and a narrow field of view setting. The IBAS FLIR is a high resolution scanned 1315x480 pixel 12-bit digital instrument which operates in the long wave infrared spectrum region. The detector scans from the top to bottom of the raster at a rate of 60 frames per second. The output video is sampled as an interlaced system, but the detector scans linearly. The pixel instantaneous field of view (IFOV) oversamples the output video raster in the manner shown in Figure 2. The gray block is the output video pixel size relative to the FLIR pixel instantaneous field of view with the optics in the narrow field of view setting.

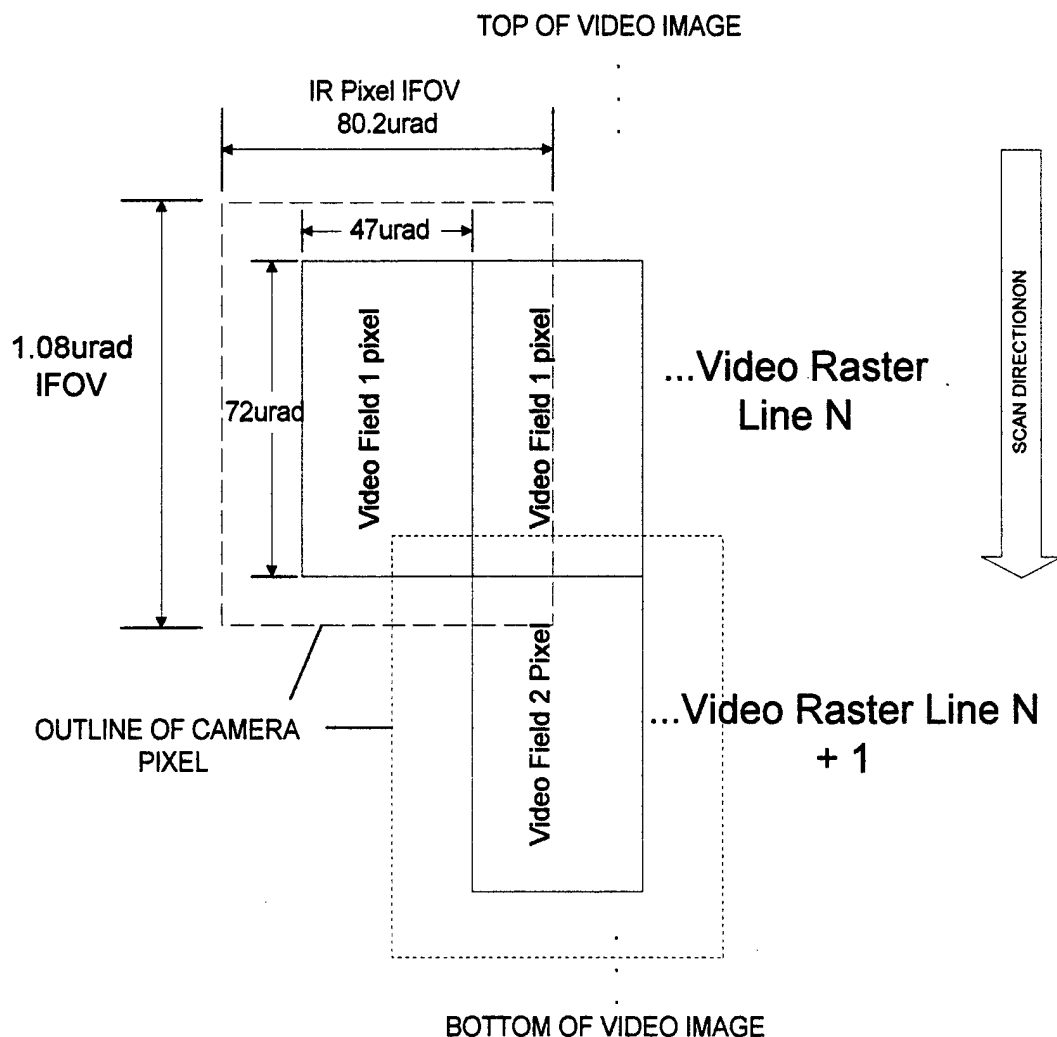


Figure 2. IBAS FLIR Pixel vs. FLIR display pixel, NFOV

The video camera in the Direct View sight is an adaptation of a commercially available Pulnix commercial CCD monochrome camera, and its specifications are included in Table 2.

A significant part of the Phase I DBITS effort involved obtaining a detailed understanding of the current level of test capability provided in the IBAS by the BSA. This was accomplished by

discussions with RTIS personnel including system engineer Duke Littlejohn. The discussions also provided insight into additional test capability DBITS could add to the IBAS.

The following areas related to the BSA were studied:

1. Mechanical Design

- How the BSA functions in the IBAS.

- The design of test functions and test features.

- How can the BSA be adapted to DBITS emitters while retaining its capabilities?

2. BSA Optical design

- Use with MIRAGE emitter

- Use with a visible emitter

A sample BSA boresight subsystem was supplied by RTIS as well as the optical specifications of the BSA collimator. The principal boresight function of the BSA has already been discussed in the overview. The specifications for the BSA showed a number of features in addition to XBT boresight features on the BSA target. This lead to a discussion with RTIS of BSA testing, which is presented in Section 2.2.2. The final mechanical design concern for DBITS is the small size of the present BSA target at approximately 0.400 inches diameter. For a DBITS system based on the BSA an infrared target and a visible target will have to be optically combined with an XBT target. An examination of the sample BSA showed a number challenges exist in the mechanical and optical tasks of combining the three sources.

The optical design of the collimator in the BSA was then examined. Of particular concern in this study were the IFOV subtended by pixels in both the FLIR and Video sights, along with the focal length of the BSA. With this information the expected optical performance of a DBITS system based on the IBAS BSA subsystem can be calculated. The results of these calculations are shown graphically in Figures 3, 4, 5 and 6 and the results are also summarized in Table 3. For Figures 3 and 4 we assume that the BSA is projecting the MIRAGE emitter to the IBAS FLIR. The Figures show the relative sizes of the projected MIRAGE pixels as the image of the MIRAGE emitter falls on the FLIR pixels.

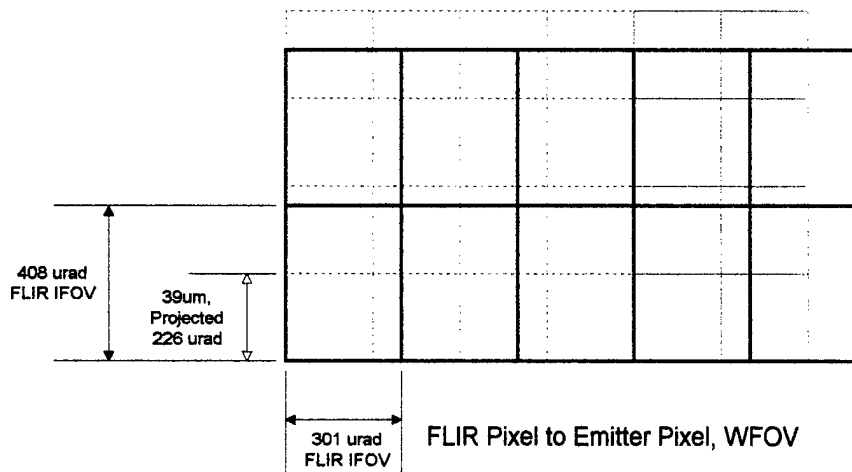


Figure 3. FLIR Pixel vs. Emitter Pixel for Wide Field of View

Figure 3 shows MIRAGE emitter projection to the FLIR pixels with the FLIR optics set for wide field of view. With the MIRAGE emitter at the focal plane of the IBAS BSA, the apparent projected size of a MIRAGE pixel at the FLIR detector is 226 microradians. The projected pixel outlines are shown with light dotted lines. The FLIR pixel IFOV is superimposed on the MIRAGE pixel size with solid lines. The drawing is not entirely accurate in that it shows the FLIR IFOV as adjacent to each other, but it does show the relative magnification of the FLIR and the emitter pixels. As will be discussed below, it is the relative magnification that is important in this application. Figure 4 shows the relative magnification of the MIRAGE emitter pixel, again with dotted lines, versus the FLIR IFOV for the narrow field of view setting of the optics. Note that the IFOV of the FLIR pixel is now smaller with respect to the MIRAGE pixel by a factor of 3.75 when compared to Figure 3. This is the switch factor in magnification of the optical systems when switching from wide to narrow field of view.

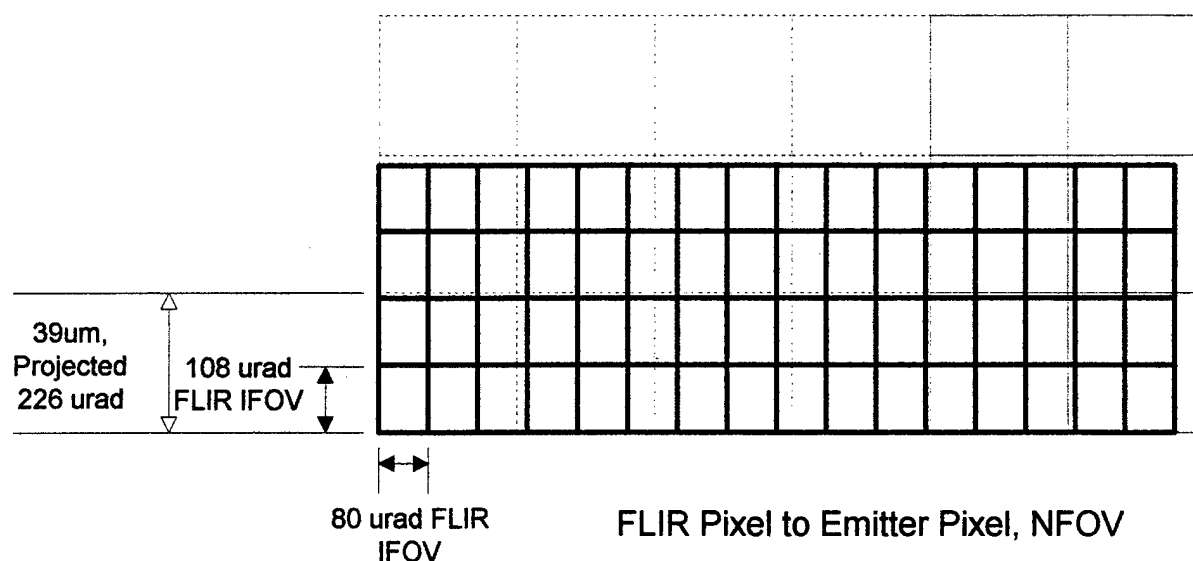


Figure 4. FLIR IFOV vs. Emitter Projected Pixel Size, Narrow Field of View.

In Figure 4 the IFOV of the FLIR pixel is now significantly smaller than the projected field of an emitter pixel.

Figure 5 and Figure 6 show the same relative magnifications of the CCD camera pixels and projected emitter for the Direct View visible optics. A square pixel with a side dimension of $13\mu\text{m}$ was chosen as the emitter pixel as this is typical of the size of the pixels of several visible emitters. Again the emitter pixels are shown with light dotted or dashed lines and the outline of the IBAS video detector pixels are shown with solid lines.

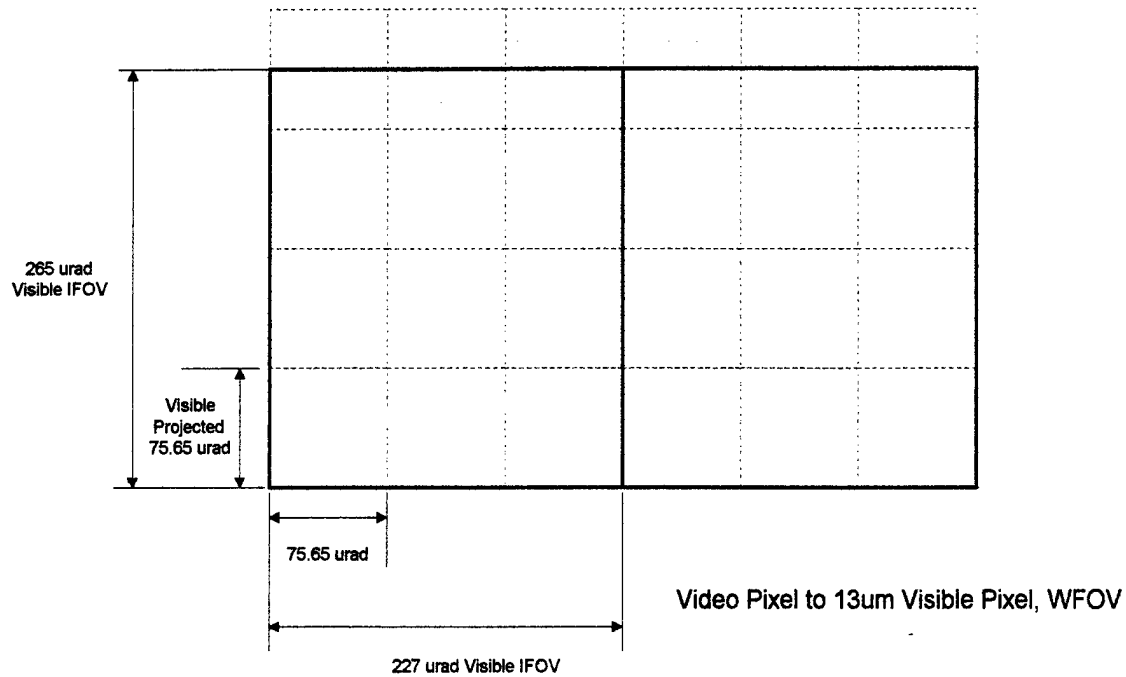


Figure 5. Relative Pixel Sizes, IBAS DVO video camera vs. projected 13μm emitter pixel, wide field of view.

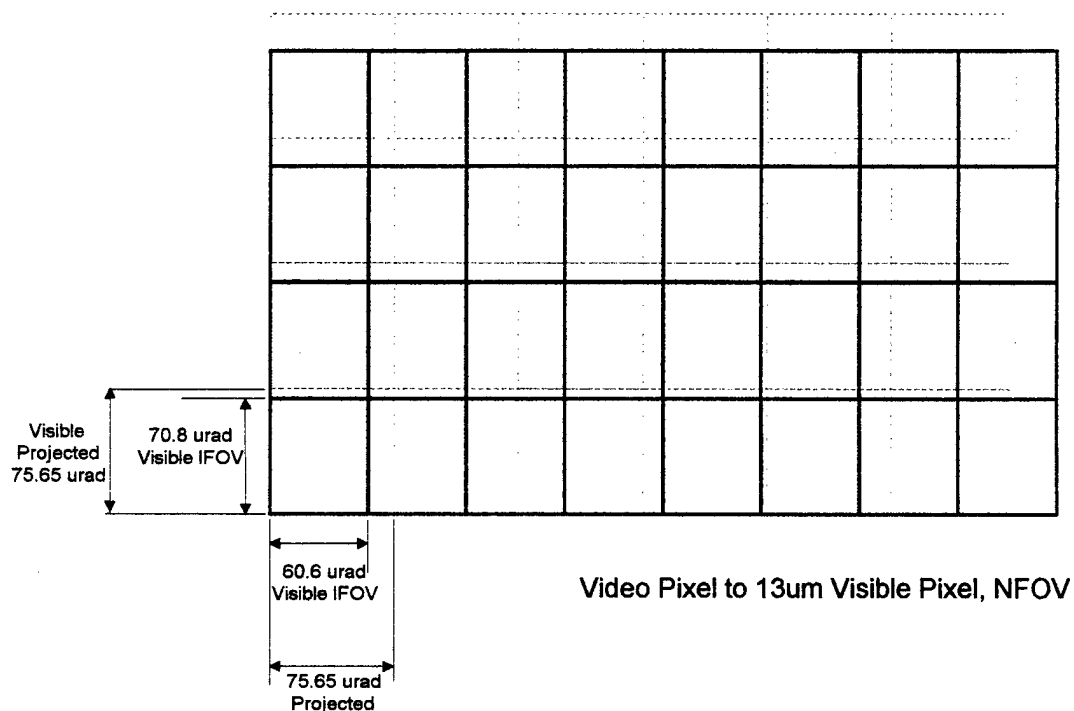


Figure 6. Relative Pixel Sizes, DVO video camera vs. 13μm projected pixel, narrow field of view

The information displayed in Figures 2, 3, 4 and 5 is summarized in Table 3.

IBAS BSA Pixel Projection	IBAS WIDE FIELD OF VIEW	IBAS WIDE FIELD OF VIEW	IBAS NARROW FIELD	IBAS NARROW FIELD
FLIR PIXELS	Raster Horz.	Raster Vert.	Raster Horz.	Raster Vert.
actual size, um	28	38		
pixel IFOV urad	300.75	408	80.2	108.8
total FLIR FOV deg	13.33	7.5	3.55	2.00
total FLIR FOV mrad	232.65	130.90	62.04	34.91
number of pixels in display raster	1314	481	1314	481
DTV Video Pixels				
size, um	11	13		
display pixel, urad	227.26	265.52	60.60	70.80
total FOV deg	10	7.5	2.67	2.00
total FOV mrad	174.53	130.90	46.54	34.91
number of pixels in display raster	768	493	768	493
MIRAGE Pixel				
MIRAGE Pixel size um	39.00	39.00		
MIRAGE Pixels Projected by BSA – urad	226.96	226.96		
Total Projected Image Size	116mrad. x 116mrad.	116mrad. x 116mrad..	116mrad. x 116mrad.	116mrad. x 116mrad.
Displaytech Visible LCD Pixel				
Visible Pixel um	13	13		
Visible Pixel as projected by BSA – urad	75.65	75.65		
Total Projected Image Size	48.4mrad x 36.3 mrad.	48.4mrad x 36.3 mrad.	48.4mrad x 36.3 mrad.	48.4mrad x 36.3 mrad.

Table 3. Pixel physical sizes and projected pixel sizes

The table shows the dimensions of IBAS FLIR and video pixels, giving both the actual physical dimensions and the angular subtense of the pixels for the IBAS optical system's two fields of view. For comparison the actual size and the projected angular subtense of the MIRAGE infrared emitter pixels and the Displaytech LCD visible emitter pixels are included in the table. The Displaytech visible emitter will be discussed in Section 2.2.4.

The relative sizes of the projected emitter pixels and the detector pixel subtense has two effects. The first effect is related to sampling of the emitters, and the second effect is the actual projected size of the entire emitter image in the detector's field of view. The relative sizes of the projected emitter pixels versus the detector pixels relates to the sampling of the emitter image by the detector system. A commonly used rule of thumb for emitter sampling based on the Schade image quality criterion suggests that there should be at least a square consisting of four emitter pixels projected onto a single detector pixel to avoid sampling errors and aliasing effects. Recently a study has presented a theoretical foundation for this rule of thumb¹. We can compare the actual projected case with the rule of thumb sampling requirements with Figures 3 and 4. The wide field of view case presented in Figure 3 shows that the area of approximately two emitter pixels is projected onto the IFOV of a single FLIR detector pixel. In Figure 4, showing the case for the narrow field of view, the FLIR pixel IFOV is covered by only a portion of an emitter pixel, and in fact the sampling rule of thumb is completely violated with multiple detector pixels sampling a single emitter pixel. In both cases the rectangular IFOV of the detector versus the square aspect ratio of the emitter tends to exaggerate the mismatch. Because the mismatch to the ideal sampling ratio is already large in both cases it is clear by inspection of the Figures that the rectangular versus square mismatch is not a dominant factor in the sampling mismatch. For both the wide and narrow fields of view the rule of thumb is violated, although it is possible that the wide field of view case might yield adequate imaging if care is taken in constructing images without high spatial frequencies, particularly along the horizontal axis.

The sampling of the visible system is shown in Figures 5 and 6. In Figure 5 the detector samples a small patch of over 9 emitter pixels, which easily exceeds the sampling rule of thumb minimum discussed above. The case in Figure 6 shows a violation of the rule of thumb with roughly one video detector pixel per emitter pixel. While the sampling ratio in the wide field of view is favorable for imaging, the sampling in the narrow field of view violates the rule of thumb and will show aliasing artifacts in the projected image.

The second effect of the relative pixel magnifications of emitter versus detector pixels is the relative size of the entire emitter in the field of view. The total field of view of the MIRAGE emitter as projected by the BSA collimator is shown in Table 3 as 116 mradians square. Compare this to the image size of the FLIR in wide field of view, which is 232.65mrad x 130.90mrad. The wide field of view is the closest to providing a satisfactory sampling ratio of emitter pixels to detector pixels, but in the wide field of view the MIRAGE emitter will not fill the FLIR image area, even in the vertical dimension. Assuming that the BSA collimator magnification could be arbitrarily changed, if we adjust the magnification so that the projected MIRAGE pixel dimension was one half of the vertical dimension of the IFOV of the FLIR pixel, the projection would satisfy the sampling criterion. Each MIRAGE pixel would appear to be 204 μ rad square, and the entire MIRAGE array would subtend 104mrad x 104mrad. This, however, is an even smaller portion of the 232.65mrad x 130.9mrad FLIR wide field image than the existing case.

The magnification of the visible array is different because the pixel size of the visible LCD arrays are generally much smaller than the MIRAGE pixel. In the wide field of view the 640 x 480 pixel Displaytech emitter subtends 48.4mrad x 36.3 mrad, compare to the total field of view

of 174.53mrad x 130.90mrad. The smaller pixel size gives an improved sampling ratio between the emitter and the detector, but it also means that a similarly sized visible emitter array cannot fill the same field of view as the MIRAGE emitter with equal magnification. This is an issue that requires further study, and will be discussed again in Section 2, the Results section.

2.2.2 IBAS Testing

The goal of this portion of the Phase I study was to understand the current role of the BSA in both factory tests and BIT. The role of the BSA in factory testing was discussed with RTIS personnel and the RTIS IBAS factory test plan was examined. In addition, the role of the BSA in BIT was discussed. The BSA's major purpose is to transfer the Xenon Beacon Tracker (XBT) boresight from the DTV/DVO optical system in the IBAS to the FLIR optical system. This facility is provided on the BSA by a laser diode with a fiber optic emitter embedded in the BSA target and with an annular IR target area around the fiber emitter. The entire BSA target can be heated above ambient temperature via a power resistor deposited on the back of the target with feedback provided by a temperature sensor. Any proposed IBAS DBITS system must continue to provide this optical and mechanical boresight alignment functionality of the BSA system.

Other FLIR test features have also been placed on the BSA target, but some of these target features are not used at present, either in factory tests or in BIT. These include targets for Modulation Transfer Function (MTF) for both optical fields of view and a linearity target. Discussions with RTIS also suggested that these and other static target tests provided by a DBITS system would have value in the future development of BIT testing.

Currently there are three levels of BIT testing in the IBAS. The first is an initial BIT that in essence is a system power supply check. There is a continuous BIT function associated with the FLIR as part of its design. Once the FLIR has reached operating temperature, the FLIR detector always scans over a controlled source during its normal operation. Finally there is an initiated BIT, or IBIT that utilizes the BSA. This has been allotted 30 seconds by the Army, but runs at about one minute. This test mainly uses the boresight alignment features of the BSA target.

2.2.3 Test Design

In order to propose DBITS tests that could be incorporated into initiated BIT in the IBAS system, a review was undertaken of the IBAS factory test plan. This task involved understanding the contents of the RTIS Test Requirements Document ITRS-IBAS-TAS-TPS. Careful attention was paid to individual tests that involved the BSA. Additional discussions were held with RTIS personnel on extending the test capability of the BSA with dynamic elements. The review and the suggestions by RTIS have lead to the selection of the tests shown in Table 4.

TEST	Visible - DTV	FLIR
Static Tests	N/A	XBT boresight
	MTF	MTF
	Optical Linearity	Optical Linearity
	N/A	Noise Equivalent Delta Temperature (NEDT)
Dynamic Tests	Tracker Tracking	Tracker Tracking
	Degraded Image Tracker Acquisition and Tracking	Degraded Image Tracker Acquisition and Tracking

TABLE 4. DBITS suggested tests.

The XBT boresight test preserves the principal function of the BSA. The XBT boresight test will require physical alignment of the MIRAGE emitter to an XBT target. The XBT can be simulated with an 840nm laser diode and a target by illuminating the laser diode to the appropriate level and modulating the illumination at the appropriate frequency that matches the operation of the TOW xenon beacon. SBIR has successfully built such a target for a factory test system for the IBAS sight. In the DBITS implementation of the XBT boresight alignment target the IR ring will have to be imaged at a precise location on the MIRAGE array. The location will be determined by the optical placement and alignment of a modulated diode source in the optical chain. The other static tests shown in Table 4, the MTF and linearity tests, are already a part of the FLIR target on the BSA, but BIT tests using these features are not currently implemented. FLIR MTF targets for both fields of view are present. These were intended for use as a built-in optical test to check degradation of optical performance over time due to optical alignment degradation or other optical degradation. The FLIR NEDT test is designed to detect degradation of the FLIR detector or the vacuum integrity of the FLIR dewar.

With the time for initiated BIT limited to a goal of 30 seconds individual tests must be designed to be highly time efficient. When testing with a DBITS system, since either the visible or IR emitter can be driven very quickly to a particular image, a standard static test can be initiated, projected and acquired by the UUT in a very short time, perhaps as little as 2 frame periods. Since static tests can be very time efficient, the recommended tests for DBITS in Table 4 include static target MTF and NEDT tests. The MTF test is a quick check of the optical performance and alignment of the system, while the NEDT is a quick check on the health of the FLIR.

The fully dynamic tests recommended in Table 4 are tracking tests for the DTV and FLIR tracking systems. A description of the dynamic tests are as follows. For simplicity the tests will use rendered images of standard targets provided by the Army. These targets will be presented in a fixed location to the IBAS for target selection and acquisition. The targets will then be moved in the projected field of view to check tracking. Our recommendation is for three image sequences, the first a clear, unobscured image, the next the same image with some calculated degradation, and the final a highly degraded version of the original. Each sequence would be presented to the tracker, with the test image making a short trip across the projected field of view

covered by the DBITS emitters and optics. The IBAS internal control system can determine if acquisition and tracking has been successful for each test.

The impact of the recommended DBITS tests on system design was evaluated. While the image generated by the Displaytech emitter has virtually no impact on power consumption and power dissipation, this is not the case for the MIRAGE emitter. While the MIRAGE emitter has a mode which results in large power dissipation whether an image is projected or not, for DBITS operation the emitter will operate in the power on demand mode. With power on demand mode power consumption and power dissipation is directly related to the thermal energy projected. A separate issue is the stabilization of the emitter substrate. The image presented by the MIRAGE emitter is an image with temperatures relative to the substrate temperature. In the laboratory version of MIRAGE much attention must be paid to providing a stable substrate and hence a stable background for imaging by carefully controlling the substrate temperature. This is particularly important when very high levels of image power are present, since this image power must be conducted away through the same substrate.

The IBAS FLIR system is very sensitive, hence for static tests an IR image with a small temperature rise from the substrate for the active portion of the test image is required. Based on tests described in the RTIS test requirements document TIRS-IBAS-TAS-TPS a 5 °C swing of the test image above ambient will be recommended for static tests. For a particularly large static target with 50% of the emitter at 5 °C above ambient the normal operation power dissipation is estimated at 1.26 watts and the image power dissipation is 0.530 watts for a total power dissipation of 1.79 watts.

For dynamic DBITS images the recommended thermal dynamic range is 50 °C above substrate. While this is not necessarily a realistic range for actual targets, power in the DBITS projected image must be limited, and automatic gain control in the IBAS will overcome some lack of realistic dynamic range. By estimating the required projected IR emitter temperature from the projected radiance received by the IBAS FLIR, we find that the 50 °C temperature range corresponds to approximately 12000 counts out of the full scale of 65536 for the MIRAGE emitter control word. The 12000 count digital input range for the emitter will provide sufficient emitter resolution to accurately project a realistic gray-scale thermal image. If we assume that the average temperature of the image is 25 °C above substrate and that this image occupies 30% of the emitter field then the emitter background power is 1.26 watts and the expected image power dissipation is 1.28 watts for a total of 2.54 watts predicted for a projected dynamic target.

2.2.4 Survey and Selection of Visible Emitter

The goal of this phase of the study was to survey the state of the art in miniature visible arrays and recommend an array for use in a DBITS system that is compatible with the MIRAGE infrared emitter. There is a wide variety of visible arrays coming to the market with diagonal dimension of less than 1 inch. The market driver for this abundance of choices appears to be the perceived need to add miniature visible displays to cellular telephones for Internet browsing. Other uses are for finders in digital cameras and as sources for high-resolution projection televisions. Various optical magnification schemes are offered, some of them essentially built in to the array.

A summary of the findings of the survey is shown in Table 5.

Manufacturer	Displaytech	Kopin	Planar	Reflection Technology	Siliscap
Pixel Resolution	640x480	320x240	640x480	640x480	800x600
Pixel Pitch	13um square	15um square	24um square	depends on optics	-
Fill Factor	85%	-	-	100%	
Illumination Method	Reflective LCD	Transmissive LCD	Electroluminescent	Linear Diode Array with microscan mirror	Reflective LCD
Stated light Level	20ftL	to 20ftL	75ftL	12 ftL	
Frame Rate	60Hz	60Hz	to 360Hz	60Hz	-
Contrast Ratio	100 to 1	80 to 1	100 to 1	5000 to 1	
Bit Depth	15 bit, 5 bit per color	256 levels	32 levels	4 bits monochrome, 12 bits color	-
Voltages Required	5V, 9V	12V, 5V	200Vpp AC, 7V, 5V, -3V	3.3 V	-
Power required	60mw	20mw	0.5 to 0.7W	191mw	50mw
Comment	High fill factor	Large arrays not yet available	Gray Scale timing not compatible with video	This device not yet available	Device in development

Table 5. Visible Emitter Characteristics

The main small display technology contenders are variants of LCD panels and a scanned diode array. The LCD's have illumination strategies which include back illumination, both via electroluminescence and via LED, and reflective front illumination. Further differentiation of LCD vendors comes from the effective fill factor of the pixels, the method of intensity modulation to produce gray-scale images and the size of the arrays. A discussion of the individual emitters shown in Table 5 follows.

Displaytech – This is a high-resolution LCD based emitter which uses a high-fill factor LCD pixel and reflective illumination. The high-speed operation of the pixel allows full color operation via successive illumination from the supplied three-color LED illumination source. The high fill factor is in contrast to traditional LCD approaches, as is the high-speed method of accommodating multiple colors are within the same pixel area.

Kopin – This is a medium resolution LCD emitter that uses a supplied LED backlighting system. The arrays are available in both monochrome and 3 color, with three-color arrays use separate red, green and blue cells for a reduced effective fill factor. This company is working closely

with Motorola in developing a cellular telephone with an integral display and optical projection system. The company appears to feel that the lower resolution array provides that best balance of cost, size, yield and manufacturability for cell-phone use, and has only long-term projections for producing larger arrays.

Planar America – These displays include a built-in electroluminescent backlight. The backlight requires a high voltage AC power source (200V) and the entire display dissipates the highest power of the group. On the other hand the illumination claimed on the data sheet is the highest of any of the arrays. This array requires multiple display cycles to provide gray scale images. This scanning method will be incompatible with detection via a CCD video imager.

Reflection Technology – This is a scanned LED solution. A linear LED array is mechanically scanned as it is modulated to build up the image. The advantages of this technology are very high contrast ratio and virtually 100 per cent fill factor. The disadvantages are the larger size required for the scanning mirror, and the added complexity of the scanning mirror. There is a strong likelihood that there will be a mismatch of the mechanical scan operation and the internal scanning of the CCD video camera.

Siliscape – This firm offers a very high resolution LCD array. The array, however, uses conventional technology. The principal innovation shown in this offering is the specifically designed optics. The optics are not compatible with use with an external collimator such as the BSA collimator. Finally it is unclear when this array will be available.

2.2.4.1 Visible array selection criteria

The following criteria were used to evaluate the visible arrays for selection of a DBITS visible emitter.

Low Power – This power requirement must complement the MIRAGE infrared emitter, which generates a modest amount of power in the creation of thermal images. It is hoped that a visible DBITS subsystem could be found that draws very little system current and dissipates very little power.

Compact Outline - In particular the optical arrangement for illumination should have a size that is consistent with mounting on the BSA.

Small Number of Power supplies - Power should be from standard voltages, and the fewer the number of voltages required the better.

Pixel Size - The size of the pixels should be consistent with the size of the MIRAGE infrared emitter pixels. If only a three-color array is available there should be little optical and fill factor penalty for using a three-color array in the monochrome IBAS environment.

Video Compatibility - The readout scanning of the emitter array should be consistent with the scanning of the IBAS visible CCD array. This requirement will help prevent scanning aliases and ease the synchronization of the emitter to the CCD camera.

The Planar Systems LCD and the Reflection technology arrays can be ruled out immediately because of doubts about their scanning compatibility with the CCD visible camera in the IBAS sight. In addition the Planar array requires a much higher power and a high voltage AC signal for illumination. The Reflection Technology emitter also requires a mechanical scanning mirror, which would add challenges to the optical integration in the BSA. Siliscope has an interesting product optically, but the optics cannot be applied to the BSA, the LCD array has no technological advantage, and its availability is suspect. The Kopin array is very small, and does not have an announced path to larger size arrays. The Kopin is also backlit, which will not allow sufficient illumination for use in a BSA-based IBAS DBITS application.

Application of the selection criteria to the survey of small visible emitters resulted in the selection of the Displaytech 640 x 480 Chronocolor LCD display for DBITS. The Displaytech array fits all of the selection criteria and also offers a large array and fill factor. As a reflective array there is considerable flexibility in varying its output. As mentioned previously, the mismatch in pixel sizes between the visible and IR arrays presents some optical integration challenges. Displaytech has announced a very large 1280 x 1024 array for production in late 1998 with a pixel pitch similar to their 640 x 480 array. This larger array could simplify the optical challenges, allowing the same magnification for both visible and IR emitters. Since details for driving this very large array will not be available until late 1998 it is left to Phase II for a further comparison of this large array to the 640 x 480 product.

2.2.5 Emitter Packaging

MIRAGE emitter power has been calculated for sample DBITS tests in Section 2.2.3. Since BIT tests must be conducted within the shortest period of time possible the total time that this MIRAGE emitter power will be dissipated will be on the order of 1 minute. In the opinion of RTIS this amount of power for this amount of time is well within the dissipation capability of the BSA and the IBAS subsystems immediately adjacent to the BSA. This power dissipation is also within the capability of the compact, permanently sealed package proposed by dewar vendor ICC of Utica NY. ICC is a commercial vendor of small, high-vacuum windowed packages, offering its products and services to infrared detector manufacturers. Although the MIRAGE emitter is based on a very large silicon RIIC, ICC stated that their Type 6 standard microbolometer detector dewar can be adapted to house the emitter. A drawing of the ICC Type 6 standard dewar is shown in Figure 7. The issue of a permanent vacuum seal was also discussed with ICC. The key to permanent sealing of silicon hybrid devices in such packages is the acceleration of the outgassing process by sustained baking of the device mounted in the dewar and under vacuum pumping. It was suggested that the MIRAGE emitter may give even better results than current microbolometers in that its materials have been optimized for high temperatures, and higher baking temperatures than possible with bolometer detectors may be possible. This work leads us to the conclusion that there is no major obstacle to achieving at least a 3-year vacuum lifetime with a small sealed emitter package such as the ICC Type 6 dewar.

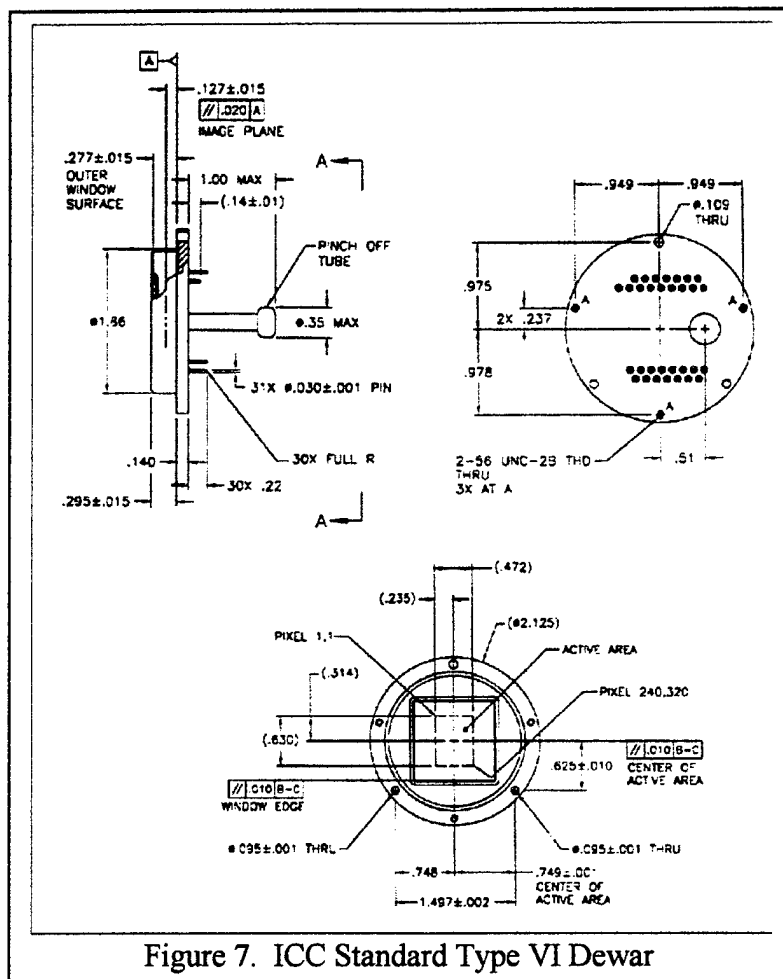


Figure 7. ICC Standard Type VI Dewar

The design of the ICC type 6 package is shown in Figure 7. Modifications to the internal well and provision for a much higher pin count for the digital emitter input would have to be made to accommodate the MIRAGE emitter, but the scope of the work does not constitute a complete redesign. The internal mounting of the emitter in the modified ICC Type 6 dewar would follow the standard practice of uncooled microbolometer IR detectors where the back of the silicon emitter is thermally bonded to a substrate, with the other side of the substrate bonded to a Peltier electronic cooler device. Emitter thermal power is pumped electronically by the Peltier device through the substrate to the metal package flange. Because the MIRAGE emitter contains an active thermal sensor circuit, and because the expected

test power levels are below 10 watts, a compact external circuit might be used to drive the Peltier device in a closed loop manner to provide thermal stabilization of the substrate of the MIRAGE emitter. This approach does incur an additional power penalty in that additional power is dissipated by the Peltier device itself while it maintains active thermal control.

One design goal of DBITS hardware, however, should be to reduce circuit complexity and power requirements. It may be possible to use the precise thermal background temperature measured by the MIRAGE substrate sensor to devise DBITS IR tests that do not require full stabilization of the emitter substrate. This would allow for elimination of the Peltier cooler, its power and drive circuit. For an unstabilized DBITS test program to be useful a precise thermal profile of the MIRAGE emitter vs. time during the test period would have to be known. With this profile, tests could be revised such that the test image commanded values were adjusted to compensate for changes in the array substrate temperature. These adjustments would be on a frame-by-frame basis in real-time. Thermal sensor information could be used to calculate additional real-time global trims to these adjustments. It is unknown what the potential accuracy limits of this method are. Also unknown is the ambient temperature range limits of this methodology. This is an area for further work and will be discussed below in the Section 3.

2.2.6 Electronics

To accommodate DBITS into an existing IBAS/BSA system, some scheme to control the infrared and visible emitters must be provided for. To fully assess the feasibility of DBITS in the IBAS a concept for emitter electronic control was developed. The electronics portion of the Phase I study focused on the details of the design of the electronics control concept system for DBITS. The particular constraints of fitting DBITS electronics into the IBAS system were considered. A brief study of the state of the art of video data compression was done to assess the utility of compression in reducing dynamic scene data storage. Finally, the impact of MIRAGE emitter non-uniformity correction on the electronic and system design of DBITS was studied.

2.2.6.1 Electronics Packaging

The DBITS electronic concept design included an assessment of the space available for control circuitry. The BSA supports only a minimum amount of electronic circuit board infrastructure. Currently there is a small printed circuit board mounted on the BSA, approximately 2.25 inches x 1.375, which is used for BSA target heater control. Additionally there is 31 pin Micro-D connector that provides interconnection between the BSA and other IBAS system elements. After consultation with RTIS a partition of the concept DBITS control electronics was developed. The electronics required for a DBITS implementation on the IBAS BSA can be successfully implemented with two key subassemblies. One subassembly will be a VME bus-based controller card. The other electronics subassembly will reside on the BSA in place of the current heater control card. The VME-based concept subassembly will include the vast majority of the functionality required to implement control of DBITS. These functions include

1. VME host bus interface
2. Local CPU control of the subassembly and remote control of the emitters
3. Test Image storage
4. Non-Uniformity Correction (NUC) coefficient storage
5. Real-time non-uniformity correction of infrared images
6. Visible and IR emitter power supply regulation
7. Visible and IR emitter image generation
8. Visible and IR emitter timing generation
9. Visible and IR emitter synchronization
10. Data communications to the BSA

The electronics elements that will be present at the BSA include:

1. Visible emitter LCD drive level translation
2. Visible emitter illumination driver.
3. Data communications to the remote VME controller.

DBITS non-uniformity correction is discussed in Section 2.2.6.2. One aspect of non-uniformity correction subsystem design is data collection for periodic correction coefficient updates. The raw data for the calculation of these coefficients could be supplied by the IBAS FLIR if the VME controller has access to the FLIR digital video data stream. The proposed location of the concept electronics is in the Fire Control System, where the FLIR data is available. The connection to

the FLIR scene data also allows synchronization of the MIRAGE infrared emitter to the FLIR scanning. An interconnect between the VME concept card and the emitters must be arranged. The possible arrangement of concept system elements is shown in Figure 8.

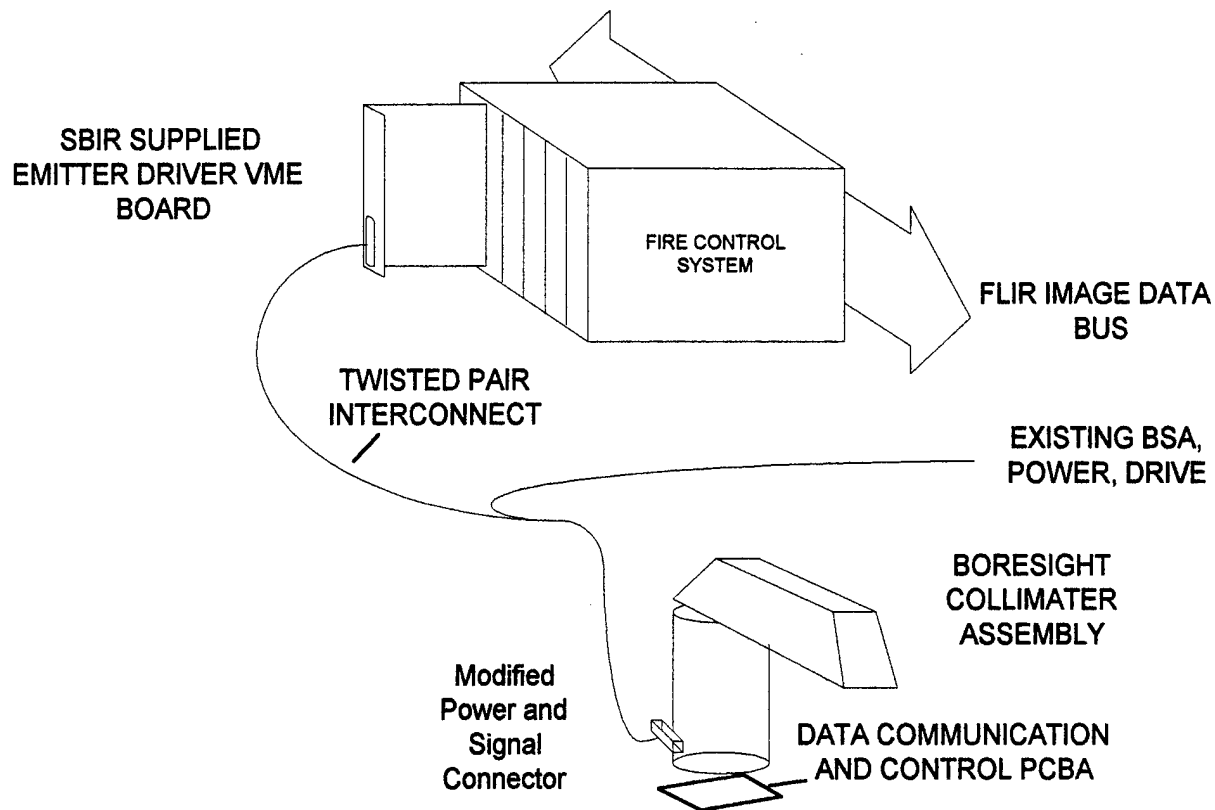


Figure 8. DBITS Emitter Driver Electronics Concept

One difficulty in locating the electronic driver remotely from the BSA is transmitting the digital data for the emitters between the controller and the BSA. The MIRAGE emitter control is the most data intensive, requiring 16 bit control words for 512 x 512 pixels. For a 60Hz frame rate this work out to a data rate of $512 \times 512 \text{ pixels} \times 2 \text{ bytes/control word} \times 60 \text{ frames per second} = 31.5 \text{ Mbytes per second}$. This is well within the data rate of the Cypress Semiconductor Hotlink serial data transmission chip set². These circuits offer a compact, relatively low-power method for high-speed transmission of digital data over fiber, coaxial cable and twisted pair links. The latter, the twisted pair link, is ideal for the DBITS application. The required link length of 4 feet maximum is well within the limits for Hotlink twisted pair connections. As mentioned above there is a small circuit board assembly currently mounted on the BSA. A slightly larger double-sided circuit board could easily accommodate a Cypress Hotlink transmitter and receiver and a separate data formatter. This board would drive the MIRAGE emitter directly while the visible driver circuits are mounted directly on the Displaytech visible emitter components. The additional interconnections required could be accommodated at the BSA by replacing the present 31 pin Micro-D connector with a 51 pin connector, which has a face that is approximately 7 per cent longer and 14 per cent taller than the present connector.

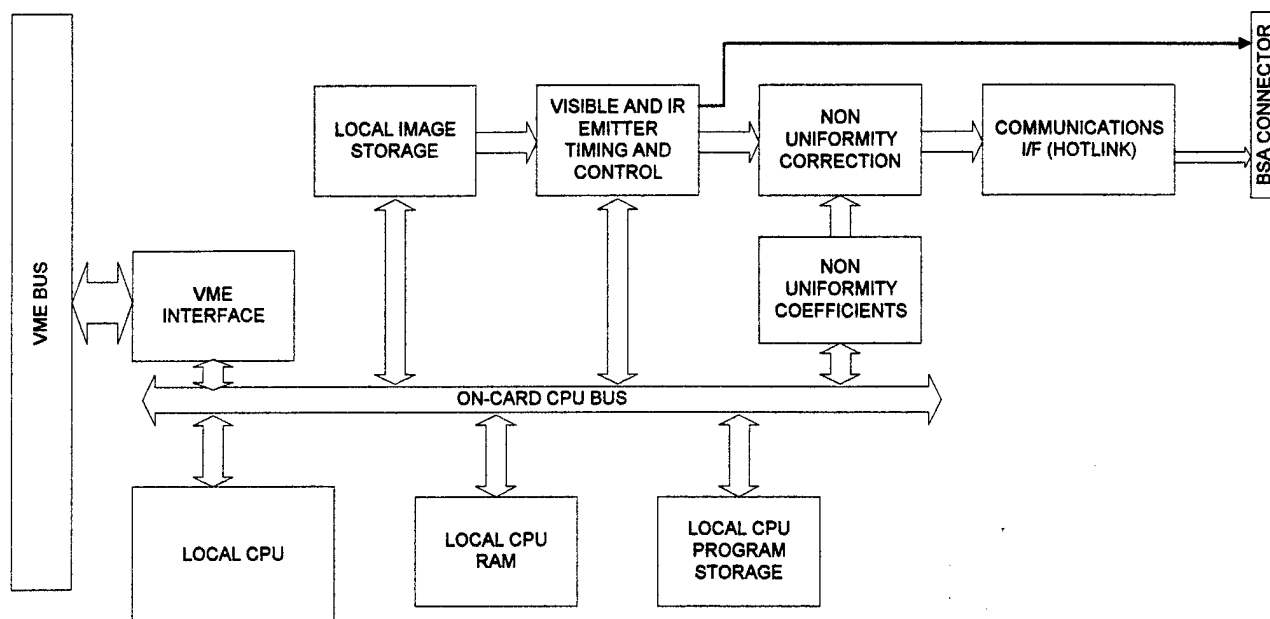


Figure 9. DBITS Concept Electronics as a VME card

The electronic elements required for a remote controller could easily be accommodated on a single 6U VME card. A block diagram of this concept card is shown in Figure 9. The VME interface also provides the interface to the FLIR digital data stream required for capturing data for non-uniformity correction coefficient calculation. The details of the non-uniformity correction circuit must still be determined and the issues involved will be discussed below.

2.2.6.2 Non-Uniformity Correction

Some correction of the inherent non-uniformity of emitter resistors must be made for all IR scene simulators. Current laboratory IR emitter systems, such as MIRAGE, require very long data collection periods and complicated algorithms for generation of non-uniformity correction coefficients. Laboratory systems use equally complicated signal processing algorithms to implement real-time correction. Since DBITS systems are intended as field systems a lengthy non-uniformity correction data collection process is more than just inappropriate, it may well be impossible.

In the laboratory a non-uniformity data collection system includes a camera that is sensitive in the same band as the Unit Under Test. For non-uniformity data collection the requirements for optical sampling of detector pixels versus emitter pixels are reversed from the Schade criterion based imaging requirements discussed in the Section 2.2.1. The emitter pixel in the non-uniformity correction case must be seen by at least 4 detector pixels to reduce detector aliasing to acceptable levels. If the IBAS FLIR is used as the data collection camera a high magnification will be required. The full discussion of BSA optical requirements is left for the Results summary in Section 3.

The laboratory real-time correction system involves an electronic signal processing system with multiple coefficients for each pixel. However, some simplification of non-uniformity correction requirements for DBITS may be possible. One question is how many data collection points (and coefficients) are required for DBITS non-uniformity correction. Since the dynamic range of DBITS tests can be carefully tailored it may well be that the number of measurement temperatures for the array and amount of raw data collected can be simplified considerably from that required by a laboratory test system. Additionally, it may be possible to design an update method for non-uniformity correction that is similar to the strategy used with infrared detectors. In the detector scheme fixed factory non-uniformity correction coefficients are updated in the field with a one-point correction process with simplified data collection and using a simple coefficient calculation process. It may be possible to design an analogous scheme wherein a detailed factory emitter non-uniformity correction is routinely updated or supplemented by a simple field process. This would simplify the correction coefficient data collection process, and may simplify DBITS real-time non-uniformity correction electronics. Further research with laboratory emitters will be needed to determine if a simplified field procedure can be designed, and what impact this would have on non-uniformity electronics. This work is discussed in Section 3.

2.2.6.3 Data Compression

The purpose of dynamic scene simulation is to provide meaningful dynamic imagery to the UUT. This involves providing streams of frames to the appropriate emitter for the duration of the simulation. In DBITS both of the proposed emitters are digital devices and the consequent requirement for digital data frame storage can present a considerable challenge for DBITS system design. Consider a sample calculation. A single frame of data for a 512 x 512 emitter contains 524,288 bytes. If we operate the emitter at 30 frames per second over a simulation time of 10 seconds the total number amount of data presented to the emitter is $524,288 \times 10 \times 30 = 157,286,400$ bytes. Compare this to 33,554,432 bytes that is standard RAM on most desktop PC's. The power and physical space that this amount of memory requires will represent a considerable portion of the final budgets for system space and power. It would appear that image compression techniques would offer some advantages if the complexity and power consumption of the compression hardware was less than the power and complexity of the uncompressed image storage memory. A short survey of the state of the art in video compression was undertaken to assess the potential for video data compression techniques to reduce data storage^{3,4}.

It was found that lossless compression techniques are available that give up to a 4 times compression of image data⁵. Above this level of compression lossy methods are used. These generally have two disadvantages. The first is that the compression ratios are not constant from scene to scene and the final compression ratio may have some scene dependence. The second disadvantage is that all lossy compression techniques are accompanied by some degree of artifacts. Metrics have been formulated to judge the level of effectiveness of video data compression algorithms by assessing the magnitude of artifacts. The metrics are based on human eye models, and the technique of the metric is to distill some aspect of the visual perception process into a simple quantity. It is tempting to use a metric to assess a particular

video compression algorithm for inclusion in DBITS, however there are two flaws with this approach.

1. Human vision based metrics are inevitably flawed by our lack of full understanding of the visual perception process. In other words they almost always result in a too simple or general a measure of transmitted image quality.
2. A human-perception-based metric is inappropriate in scene simulator work since the perception of the scene is done by a machine, not by a human. Artifacts that may be acceptable because they are below the level of perception of a human observer may be completely unacceptable for a target tracking system. This latter observation will also be highly dependant on the tracking algorithm.

Recently there have been studies and field trials with human observers which attempt to overcome the first flaw. These studies presented individual observers with scenes with various levels of image degradation from compression artifacts and assessed the observers perception of targets and false targets. These studies, however, do not address the second flaw. To date there does not appear to be any work published that addresses the problems of compressed video data being presented to trackers or to machine vision systems in general.

While artifact-free compression techniques do not offer much better than the 4x reduction of lossless methods, it should be possible with careful image design to develop dynamic DBITS tests that are data storage efficient. One particular difficulty standard compression methods have with video signals is in dealing with noise, both within a frame and from frame to frame. Software techniques to carefully tailor DBITS dynamic scene frame data to eliminate image elements that are noise-like, or that differ only in the lowest two digital bits can maximize the efficiency of lossless algorithms. Other techniques could use DBITS electronics CPU horsepower to build up some parts of dynamic images from compact description files in a manner similar to that used in the PC 3-D gaming software industry. It is left to Phase II to further develop and apply these methods.

3. Results

3.1 Study Summary

From the studies conducted for DBITS Phase I the following results can be summarized.

1. Selection of the Visible Emitter. The Displaytech emitter represents the best compromise in compact displays with respect to power, number of pixels, and IBAS CCD video camera compatibility. This display offers a number of additional advantages in fill factor, illumination strategy, and a path to larger displays. The latter is particularly important in that this may represent a method to overcome the difference in pixel size between miniature visible displays and the MIRAGE IR emitter.
2. A set of recommended DBITS tests have been proposed. These tests are summarized in Table 4.

3. A MIRAGE emitter compact vacuum package has been identified. Although mounting of the MIRAGE emitter into a compact vacuum package is feasible, and greater than 3-year vacuum lifetime is likely to be achieved, there still are unknown issues that must be resolved in the laboratory before fully committing to such a package. This is particularly true with the current state of the art in infrared emitters, which are expensive to fabricate. Permanent packages do not lend themselves to re-opening and easy retrieval of the emitters at the end of experiments

The packaging question that remains is the proper handling of emitter power dissipation. It is proposed that a closed loop electronic image processing method of dealing with the rise in substrate temperature during emitter operation will make active power management of the emitter and emitter package unnecessary. Further experimental work will be required to determine whether this proposed method is useful.

4. A visible and infrared emitter drive electronics concept has been presented. The location of electronics elements, and the scale of the circuit development has been shown.
5. A number of open issues remain to be addressed. These include:
 - a. Whether the MIRAGE emitter can be run with no active thermal management with electronic compensation for substrate drift as stated in Result 4.
 - b. Can a simplified procedure for MIRAGE non-uniformity data collection be found?
 - c. Is there a way to reduce the number of coefficients, whether factory or field generated for non-uniformity correction given the limited dynamic range of the MIRAGE emitter in DBITS tests?
 - d. Can the IBAS FLIR be used for non-uniformity correction raw data collection? There are mutually exclusive competing requirements of optical sampling of the MIRAGE emitter pixels by the FLIR pixels, one is the Schade based image aliasing criteria and the other is pixel sampling for non-uniformity data collection purposes.
 - e. The final open issue surrounds the BSA collimator itself. As mentioned above there are mechanical and optical challenges in adding the MIRAGE emitter, the visible emitter and an XBT target to the existing BSA. Moreover the BSA collimator does not present an ideal optical environment for DBITS use. While the BSA collimator can project a reasonable quality image when the IBAS is in the wide angle mode, there is a size mismatch between the image in the visible and the infrared caused by the mismatch in emitter pixel sizes. The BSA collimator is not at all suited to projection of either visible or infrared imagery to the IBAS in the narrow field of view. The narrow field of view could be eliminated from the DBITS testing, but this field of view is used with the target in the current system, and some existing functionality would be lost. With the present BSA collimator the narrow field of view is useful for DBITS non-uniformity corrections

data collection, but any change in the collimator designed to improve narrow field of view imaging would most likely eliminate the data collection use. There are potential changes and tradeoffs to be made in the IBAS Boresight Assembly.

3.2 DBITS Feasibility

From these results the following conclusions on DBITS feasibility can be drawn.

1. The mechanical aspects of DBITS are highly feasible. It was thought at the start of the study that compact packaging for the MIRAGE emitter might be a significant stumbling block. Instead a compact solution, based on off-the-shelf hardware was discovered. This package, and the compact Displaytech emitter can be mounted, with some challenges, onto the BSA.
2. The electronics aspects of DBITS are highly feasible. An electronic system layout in the IBAS has been shown and the fit of the components appears quite good.
3. The usefulness of a DBITS system in the IBAS appears to be good for images projected with the IBAS optics in the wide field of view mode. DBITS can contribute by making existing IBIT more efficient and adding dynamic testing.
4. The optical feasibility of DBITS with the BSA is challenging. The collimator presents obstacles to effective imagery in both fields of view. These obstacles will result in some loss of functionality of the BSA in the narrow field of view, in particular.

4. Recommendations

SBIR recommends that DBITS be pursued by the Army with a DBITS proof-of-concept demonstration. SBIR's recommendation is to not invest time and effort in redesigning the BSA and its optics for a DBITS proof of concept test and demonstration. We recommend a simple optical approach be taken in DBITS Phase II and to concentrate the DBITS Phase II effort on proving the DBITS concept hardware. Therefore SBIR recommends that further work on DBITS take place in two areas.

1. The first area would be the fabrication of a DBITS demonstration system. This system would be used to validate the concepts of DBITS testing with an IBAS system, but without using the BSA directly. The DBITS tests identified in Phase I could be validated with hardware that is based on a compact laboratory system design. SBIR estimates that a full optical and mechanical reworking of the BSA for DBITS testing would by itself consume almost all available funding available for DBITS Phase II. SBIR recommends that for the demonstration system that a simple substitute optical collimator can be designed for test purposes. If it is desired that the collimator fit in the physical outline of the BSA, this requirement can be added to the specification of the collimator. A block diagram of the proposed demonstration system is shown in Figure 10. The system includes a custom collimator, a target that optically combines a MIRAGE emitter in its laboratory package, a Displaytech Chronocolor Display, and modified MIRAGE laboratory control elements. Because the demonstration system for Phase II would be based on stable, precise laboratory projection equipment, the second recommendation can also be performed with the system shown in Figure 10.

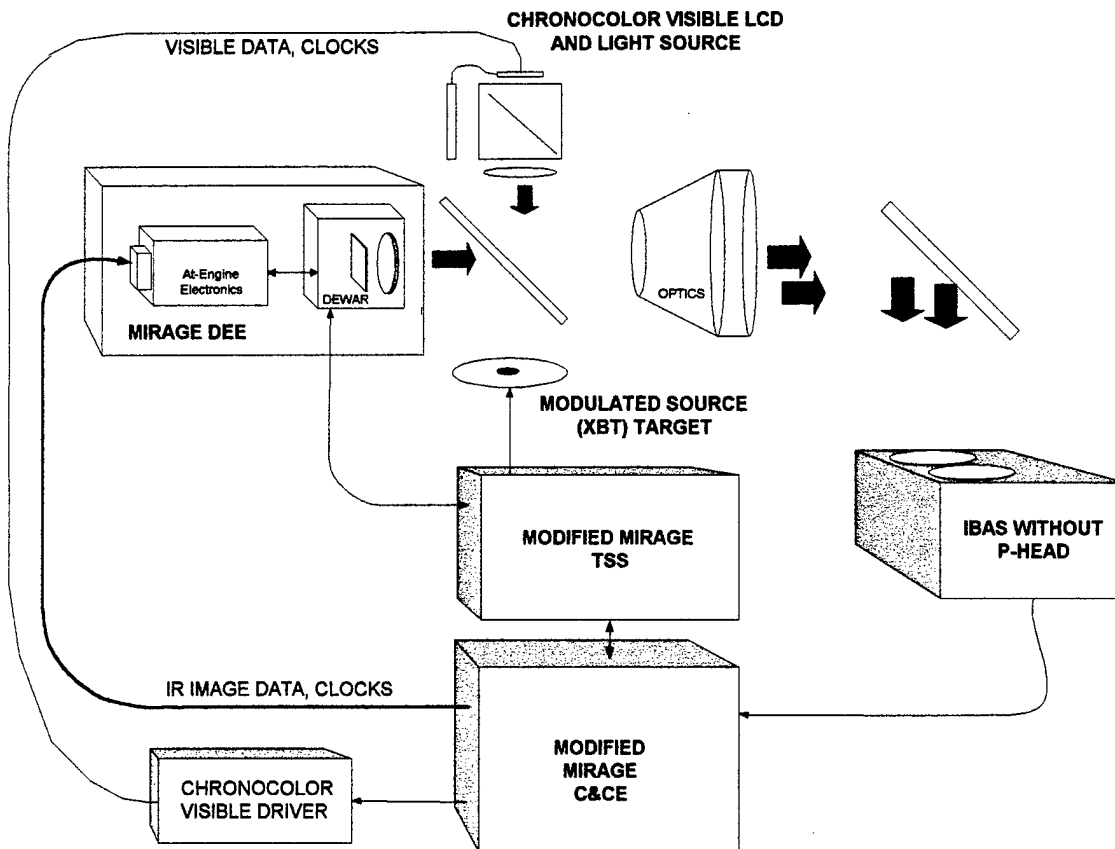


Figure 10. Proposed DBITS Demonstration System.

2. A research program focused on open DBITS technical issues uncovered in Phase I is the second recommendation to the Army for DBITS Phase II. The first area of research would be into the stabilization of the IR emitter background during DBITS testing. As described above, it may be possible to simplify DBITS hardware and reduce power consumption considerably by reducing or even eliminating the need for active and passive stabilization of the DBITS emitter substrate while presenting DBITS IR tests to the UUT. One approach to be tested is the accurate creation of an artificial background and active portion of a test pattern. Both parts of the test pattern will be at a to-be-determined number of degrees above initial substrate temperature. As the test presentation continues in time the hypothesis of this portion of research is that the rise in the non-stabilized substrate temperature during presentation of the DBITS tests can be accurately compensated for in both the active and background portion of the test patterns by adjusting the levels of the pattern elements on a frame by frame basis in a predictable manner. The objective of this portion of the research program will be to test this hypothesis and to discover the feasibility of running DBITS tests without active stabilization of the IR emitter substrate. Experiments will be designed and tested that eliminate or reduce active thermal stabilization of the MIRAGE emitter. Trials using both open and closed loop thermal substrate compensation methods will be devised and run. All trials will be compared against a baseline of fully stabilized tests which will be run using all the facilities of the MIRAGE DEE thermal management system.

The second area of work for the Phase II research program will focus on non-uniformity issues. SBIR recommends trials and experiments in two areas to be conducted using the demonstration system components. The first phase of non-uniformity experiments will be designed to determine the most effective method of collecting data for field non-uniformity correction procedures using the UUT as the collection camera. The issue in this part of the research is that there have traditionally been different optical requirements for scene projection and for non-uniformity data collection. The scene projection optical requirements have included the fact that UUT pixels significantly oversample emitter pixels by at least a factor of two in each linear pixel dimension. Many schemes currently in use or proposed for collection of data for non-uniformity correction on the other hand reverse this requirement where each camera pixel undersamples the area of emitter pixel by a factor of at least two in each linear pixel dimension. The question is whether an effective data collection method can be devised using just the single optical requirements for proper projection. For this portion of the research the recommendation is that experiments be conducted with both the demonstration optical system and the IBAS and standard MIRAGE Calibration and Radiometry System (CRS) components, including the CRS camera and data collection system. A series of trials using various methods of isolating individual emitter pixel performance will be devised and run using the IDDS system. It is proposed that the most early trials be run with the MIRAGE CRS components as they will provide the most efficiency and accuracy in data collection. Promising methodology conforming to standard projection optical requirements can also be tested on the IBAS sight using the IRWindows image capture system for data collection and verification of results.

The second part of the non-uniformity research is the investigation of simplified methods for field non-uniformity updates. The trend in laboratory IR emitter systems that must project high accuracy scenes over a very wide range of projected temperatures is for very elaborate non-uniformity corrections schemes that require emitter data collection at 32 or more individual emitter drive points. Since DBITS image dynamic ranges are a small portion of the full range of a laboratory system, there may be a way to simplify the data collection process. Future DBITS systems must demonstrate an accuracy and stability such that they can be corrected initially at the factory or the repair depot with only minor updates required in the field. The research effort in this phase will be directed towards a methodology that emphasizes a factory-applied correction with a simplified field update procedure. For this research simplified non-uniformity correction procedures will be devised and tested using the MIRAGE CRS components. If favorable results from the first part of the research have been produced, data collection methods developed in the first part of this research will be used to validate both phases of the non-uniformity correction effort.

5. Commercialization Feasibility

Santa Barbara Infrared, Inc. (SBIR) designs and manufactures the most technologically advanced electro-optical (E-O) test equipment available in the industry. Instruments are available as COTS (Commercial Off the Shelf) to satisfy virtually all E-O test applications. SBIR also supports many major military programs with customized test solutions (LANTIRN, TADS, CASS, IFTE, ITAS/IBAS, etc.). SBIR leverages and couples the technology gained from these military programs with its core commercial technologies to expand its Standard Product Line

and hence COTS equipment availability. For example, our commercial Model 920 Smart Blackbody was originally developed for LANTIRN.

The DBITS Demonstration System will enable SBIR to expand its work on the MIRAGE System and thus ensure further development of this advanced dynamic IR scene generation technology. Miniaturization and consolidation of electronics will drive costs down and decrease size while increasing performance. The incorporation of additional channels (visible and XBT) will enable multi-sensor suite testing. Recommended efforts in the areas of testing and calibration are intended to refine the current schemes and methodologies. The recommended optics task is the first step towards dealing with the issue of downsizing which is a requirement if this technology is going to find more universal application. All of these factors should enable a direct path to a more widespread application base for the Generation 3 Scene Simulator with the ultimate goal of having the hardware recognized by the industry as COTS.

5.1 Commercial Applications

Immediate commercial applications for IR scene generation technology are tied to the aerospace industry for IR missile and IR imager testing and evaluation. Current IR missile testing is expensive and time consuming. IR scene simulators will enable the aerospace engineer to "work" on the missile while the missile is in simulated "flight." This should dramatically reduce testing costs and cycle times for new missile systems.

Another application for Generation 3 scene simulator technology is laboratory/ production testing of IR Imaging Systems. Modern systems incorporating search/track algorithms can only be tested utilizing existing static technology. Generation 3 technology will enable the test engineer to fully exercise the system in the laboratory or production line, thus testing the system in a manner more consistent with the way it will be used.

In the 3-5 year time frame, the Pilot Vision Enhancement (PVE) Market is viewed as having a real opportunity for the application of DBITS technology. These PVE units are designed as landing aids for commercial aircraft applications. It is estimated that the PVE Imaging Market will grow by a factor of 10, from approximately \$5.0M to \$50.0M per year, from 1999 to 2002. This window of 3-5 years from now is very much in line with the DBITS development cycle. Due to the critical nature of these markets, DBITS has many additional applications.

Other commercial applications in the industrial, medical, and R&D markets will most certainly exist, however, it is not as clear at this point as to which ones have distinguishable potential.

5.2 Military Applications

There are numerous potential uses of Generation 3 Scene Simulators in military equipment. Any of the FLIR systems in the military inventory that can benefit from DBITS, including targeting, navigation, fire control, search & track, tactical & strategic surveillance systems and munitions

(missile seekers). We estimate the U.S. Domestic market size for such FLIR systems to be on the order of \$500M per year, as an average, for the years 1998 through 2002. Where the direct installation of DBITS subsystems into FLIRs is inappropriate because of size or cost constraints, there is an opportunity to provide portable systems for field tests, and depot level dynamic test stations that will benefit from the advances made in DBITS. These portable test applications will provide a valuable tool to the flight engineer & squadron leader as munitions could be tested in situ, thus insuring E-O system functionality prior to deployment. We see these portable applications to be numerous across all branches of the Military (Tri-Services)

Military training systems will also benefit from inexpensive, compact simulator technology. *GI* training using simulator projectors coupled with specialized high-speed interactive simulation engines can provide a realistic learning experience without the expense of a special test range and test range equipment. Since training is not necessarily tied to the range it can be more flexible and training updates in the field are easily accommodated.

6. References

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7. GLOSSARY

Abbreviations

BSA	Boresight Assembly
CPU	Central Processing Unit
DBITS	Dynamic Built-in Test/Simulation
DEE	Digital Emitter Engine
DTV	Direct view television
DVO	Direct View Optics
FLIR	Forward Looking Infrared
IBAS	Improved Bradley Acquisition System
IR	Infrared
IFOV	Instantaneous Field of View
LCD	Liquid Crystal Display
MIRAGE	Multi-Spectral Infrared Animation Generation Equipment
MTF	Modulation Transfer Function
NFOV	Narrow Field of View
NUC	Non-Uniformity Correction
RIIC	Read-In Integrated Circuit
RTIS	Raytheon Texas Instruments Systems
SBIR	Santa Barbara Infrared, Inc.
TSS	Thermal Support Subsystem
UUT	Unit Under Test
WFOV	Wide Field of View
XBT	Xenon Beacon Tracker